Section 2: The Networks for Messages

Topic 13

Digital Communications

Objectives

Welcome to Topic 13.

This topic will help you chose the correct operating mode for each situation in an emergency or disaster communications environment.

Student Preparation required:

You should be generally familiar with phone (voice), CW, packet, and other digital modes.

Introduction

Your purpose as a communicator is to provide accurate and rapid transfer of information from one place to another. To do that job well, you must understand the strengths and weaknesses of each mode of communication. In addition, you must be thoroughly familiar with the needs and priorities of the agencies you are serving. Some messages must be delivered quickly, while others are less urgent. Some are detailed, while some are simple. Sometimes you should not even use radio.

Digital Modes

Traffic nets handling large volumes of written or high-precision traffic should consider using one of the digital modes. Digital modes can be used to transmit long lists such as health and welfare traffic and logistics messages involving lists of people or supplies. Some digital modes provide virtually error-free transmission, and relays can be accomplished by retransmitting the received digital message without having to retype it. Packet systems can provide automatic relays. Digital modes that do not provide automatic error correction should only be used when clean and interference-free signals can be guaranteed. These modes include RTTY, AMTOR mode A, and PSK31 in BPSK mode.

HF: While there are many “favorites,” over the years the most commonly used digital modes for emergency HF operations appear to be packet, AMTOR mode B, Olivia, and PSK31. But this is

changing with new options to interface with the internet. In general, antenna and radio considerations are similar to voice or CW operation, although certain digital signals require less power than voice modes to achieve the same effect. Modes such as WSPR, while not particularly useful for message handling, can provide information on current propagation characteristics.

VHF/UHF: The Terminal Node Controller, Version 2 (TNC2) FM packet is the most common mode used on VHF and UHF frequencies. The antenna and coverage considerations are the same as for FM voice.

Packet: Packet communication is error-free in point-to-point "automated repeat request" (ARQ) or "forward error correction" (FEC) broadcast modes. The most effective way to send messages via packet radio is to use a "bulletin board." The sending station "posts" his or her messages on the bulletin board and other stations can then retrieve their messages at will. Urgent messages can also be sent directly to the receiving station if needed.

Bulletin board stations are also useful when several stations are sending messages to a single point, such as a command post, weather service office, or emergency operations center. Similarly, bulletin boards can be useful in handling outgoing traffic. Stations with traffic can post messages to the bulletin board. The traffic handlers can periodically pick up the traffic and send it to the outbound NTS nets.

If your group is using FM packet, ask if transmissions are simplex point to point, or if nodes, digipeaters, or bulletin board forwarding systems are being used. You will need to know which frequencies and modes are used and for what purpose, what their call signs or aliases are, and how various parts of the system interconnect. A consideration is that multipath propagation may distort digital signals enough to cause failure when a voice might still be understandable. The solution is the same as in voice mode — move the antenna a few inches or feet until you get a clear signal.

AMTOR Mode B: AMTOR mode B (also known as FEC mode) is an advanced teletype mode with forward error correction, making it ideal for high-precision messages over long distances.

Olivia: Olivia is designed to work in high-noise conditions on HF and VHF/UHF. The signals can be decoded even when they are 10 to 14 dB below the noise floor. It also decodes well when other noise conditions are present such as QRM, QSB, flutter, and aurora conditions. Olivia is available in *Ham Radio Deluxe*, *fldigi*, *MultiPSK*, and *MIxW*.

PSK31: The ability of PSK31 to be usable in very poor conditions makes it ideal for HF emergency communication. In addition, the efficiency resulting from the very narrow bandwidth of the PSK31 signal means that even a low power transmitter will work quite well. There are two PSK31 modes: BPSK, which has no error correction, and QPSK, which has forward error correction. BPSK should be used unless the received copy is poor, since QPSK is 3dB less efficient and requires more careful tuning. Under all but the worst conditions, BPSK will provide perfect transmissions.

Packet Teleprinting Over Radio (PACTOR): This is a combination of packet and AMTOR. It

is designed for HF use only, and it combines the best features of both. PACTOR uses FEC and ARQ modes and a standard keyboard. PACTOR is quite robust (more so than AMTOR and RTTY), but it can be slowed by poor band conditions.

TCP/IP Packet: TCP/IP internet protocols and network services are useable on packet radio. TCP/IP systems have advantages over conventional packet protocols that could be important in amateur emergency communications operations. One IP system is JNOS, which has extensions written by Johannes Reinalda, WG7J, to the original Network Operating System (NOS) written by Phil Karn, KA9Q.

JNOS is a TCP/IP oriented e-mail system. If you're familiar with internet e-mail, you'll be familiar with typing e-mail into JNOS. It sends e-mail via SMTP mail protocol and can interface to the internet. A JNOS station can relay packet radio messages to the internet and vice versa, unattended. It will print incoming messages automatically on to a printer, unattended. If the printer is a cut-sheet printer such as an inkjet or laser printer, individual messages will automatically appear on separate sheets.

The operator can open up to eight windows for multiple sessions for messaging. It has a ninth window for command mode for controlling the system, and a tenth window for debugging. It can multitask efficiently on a 386 computer with one megabyte of memory. In a minimal configuration, it can run on a PC/XT (640KB 8086) as an end-node station. It supports multiple communications ports and multiple radio/TNC combinations. It is shareware and is available on the internet.

APRS: While not a message handling mode, APRS is a digital information mode with applications in emergency communications. Originally called "Automatic Position Reporting System," this mode is now sometimes called "Automatic Packet Reporting System," owing to new applications of the technology. The newest application of APRS is the automated reporting of data from digital weather stations. The original application for APRS, developed by Bob Bruninga, WB4APR, is to track a station's location. A GPS receiver is connected to a computer, and its position information is transmitted to other stations using APRS packet software, displaying the location of the sending station on a map. APRS also has a messaging mode similar to "instant messaging," in which quick one-line messages can be exchanged online.

APRS has two obvious applications for emergency communications. First, the locations of various emergency vehicles can be tracked visually in real time in an automated and unattended fashion. Second, weather and other environmental data can be reported automatically in near real time. Both applications can both speed data acquisition and reduce the workload on critical emergency nets.

D-STAR

D-STAR is a digital system, but it has significant differences from some other systems. D-STAR allows for both voice and data communications. Even small handheld radios can send and receive short digital messages. D-STAR uses VHF, which allows for a slow bit rate, or UHF, which is much faster. It does not currently have HF options. D-STAR also uses the internet for

long-distance messaging. For example, a short digital message may be composed on a handheld portable radio, be sent over the air to a D-STAR repeater, enter the internet, be received by another D-STAR repeater in another state, and then sent out over the air to the addressee.

DMR

DMR has taken off in many areas and adds a new element to the VHF/UHF digital voice offering. Like other digital voice and analog voice modes, DMR provides another means for communications, and many ARES groups run DMR nets. DMR does require specialized equipment, and radio programming is far more involved than with analog voice radios. Before investing in additional radio equipment, check to see if DMR is in use in your area.

System Fusion

Until now, FM repeaters were used only for conventional FM communication, and digital repeaters were used only for digital communication; there had been no option for cross-communication in a single repeater. However, System Fusion can be used in multiple ways: for digital communication, for conventional FM communication, and even for internet communication. Most importantly, System Fusion enables intercommunication between all users. This is enabled by the Automatic Mode Select (AMS) function used in System Fusion. With AMS, the modulation of your station is automatically selected according to the received signal. If a member transmits in conventional FM, the other radios in the System Fusion automatically select their modulation to conventional FM to communicate between all members.

By simply replacing the current conventional FM repeater station with a System Fusion AMS digital repeater, you can continue to use the conventional FM communication, as well as the repeater for digital communications. Because the System Fusion repeater is capable of converting and transmitting digital communication to conventional FM communication, you can intercommunicate with members using either conventional FM communication or those using C4FM digital communication. Previously, when a repeater group planned to use a digital system, all other members of the club using conventional FM communication needed to purchase equipment capable of digital communication. With System Fusion, digital communication and conventional FM communication can join in a single multiple function system.

Winlink

The Winlink system utilizes various modes, including PACTOR, packet, Telnet, and sound card mode WINMOR, to send email via radio.

Winlink requires *Windows* Vista or later and .NET 3.5. The client Winlink Express is the most flexible in supporting all the above modes and connection types. This client allows for additional call signs and is aimed at the individual operator.

Paclink, the original Winlink mini e-mail sever from the Winlink development team, may attach an SMTP Mail client such as Outlook, Mail, etc., and can serve multiple VHF/UHV/Telnet combinations with hierarchal routing scheme. Modes available are PACTOR, packet, and Telnet. Connection types are limited to client to gateway. Paclink does have a use function inside of a LAN environment for either web-based or standard SMTP Mail clients.

Standard call signs may be used as well as temporary tactical addresses, which attach to call signs to be legally sent over the Amateur Radio spectrum.

Airmail is an older program and is not maintained by the Winlink development team. It provides PACTOR, packet, and Telnet capability. The target user is the amateur maritime community while cruising off shore. In addition, there are many programs that are used for the Winlink gateway stations that are not from the Winlink development team. Each has a specific purpose, and programs from other sources are also available to make gateway stations more flexible. They include BPQ32, which may have a Winlink gateway function enabled.

Another flexible program is *AGWPE*. This allows frame-by-frame switching between packet programs and TNCs. Paclink and RMS Packet do have interfaces for this program.

Gateway station locations and frequencies for nodes can be seen on the Winlink website under Tools/RMS Map or Tools/RMS List. Both entries require you to select the RF mode of operation.

The Winlink system is a work in progress, and all users need to keep their installed programs up to date. Also, note that all accounts will expire 400 days after the last use.

In the US, for civil service authorities and their critical infrastructure partners, there is another non-amateur spectrum use of the Winlink radio e-mail system. Amateurs may become involved only under NCC SHARES member agency guidance. For more information, see https://www.dhs.gov/shares

Mesh Networks

In 2001, the ARRL HSMM Working Group created a high-speed digital network for the Amateur Service. What began as the “ARES-MESH” later became known as High-Speed Multi-Media, hence HSMM-MESH. The primary purpose for HSMM is to provide a means for emergency communications to be carried on over a high-speed wireless data network that can handle voice, data, and video communications. For several years, Broadband Hamnet, or BBHN (www.bbhn.org), led the development of HSMM, utilizing Linksys desktop routers to establish neighborhood networks. Today the technology is advancing through the efforts of the Amateur Radio Emergency Data Network, or AREDN Project (www.arednmesh.org/). In its current form, utilizing environmentally robust routers from the wireless ISP industry referred to as “nodes,” multi-megabit links are now feasible across spans of 50 miles or more.

As an example of what can be done with MESH, ham radio operators throughout an eight-county

region of Southern California have coordinated their implementations using a series of interconnecting backbone nodes. Their efforts have produced a mesh capable of supporting Memoranda of Understanding (MOUs) with agencies virtually anywhere within Southern California serving a population of over 16 million people. HSMM can also be used in the day-to-day aspects of Amateur Radio communications.

For a list of supported devices, check the AREDN and BBHN websites.

https://www.arednmesh.org/

http://www.broadband-hamnet.org/

It is easy to reprogram the routers with the free software developed by these groups, to operate over the 802.11b/g Wi-Fi channels in the Part 15 spectrum, and also, in the case of AREDN, 802.11b/g/n support on similar channels entirely within the 900 MHz, 2.4 GHz, 3.4 GHz, and 5.8 GHz Amateur Radio bands. Remember, no hardware modifications are necessary. The software converts the router to a microwave mesh node. Each node of the mesh network can acquire data from an external device and relay data acquired by the other nodes. As the nodes are powered up, the software enables each node to discover other nodes within range, form network paths, and transfer data automatically.

An HSMM node is an endpoint connection *and* a repeater. If one endpoint cannot see its desired destination but can see nodes in between, the data will hop from one to the next until the final connection is made completely automatically. If one repeating node falls out, the software automatically reroutes traffic through other available nodes.

A Technician-class Amateur Radio license is required to operate these in the ham bands.

All sorts of devices can be connected — computers, webcams, VoIP phone, servers, anything that "talks" over a computer network. For the most part, the services you establish will be dependent on the requirements of the agencies you intend to serve.

- A simple example is a large ARRL Field Day site with several stations each with a laptop and a connection to a MESH network, if one node has internet connectivity, which can be shared with other nodes on the mesh, so every node at the FD site can have internet access.
- In a more complex example, the MESH may be used to provide e-mail connectivity, PBX-based telephone service to desktop VoIP phones and cell phones running VoIP applications. You may even be able to restore cell-provider services to a disaster site.

In more complex applications of this technology, it behooves one to become an expert in optimizing these networks for their intended purposes and configuring these higher-level services. In all cases, care must be taken to ensure the network is operated within your Part 97 license grant.

Ham radio operators have already constructed MESH infrastructure in many cities throughout

the US, so check the developer sites listed above for more information.

Amateur Television (ATV)

There are two forms of ATV — slow-scan and fast-scan. Fast-scan ATV is live, full-motion TV similar to what you see on commercial TV, but usually at reduced quality. Slow-scan ATV uses a voice-grade channel to send a still picture line by line. It can take more than a minute for a color picture to be transmitted.

ATV has a number of emergency communications applications, all of which involve letting emergency managers see what is going on in the field without ever leaving their offices. ATV crews usually take a passive "observer" approach and avoid interaction with bystanders to ensure that a situation is accurately represented. No emergency communications ATV transmission should ever be "staged" for the camera.

Narrow Band Emergency Messaging System (NBEMS)

Narrow Band Emergency Messaging System (NBEMS) is an integrated suite of programs that can be used for both emergency communications and recreational operations. The software is designed to run on nearly any modern computer and can easily interface with almost any radio.

NBEMS uses the either the soundcard of your computer or an external sound card connected to your computer's USB port to generate digital audio signals that are output from your computer's speakers or headphone jack and transmitted. Incoming signals are routed to your computer's soundcard by a microphone connected to the computer (either built in or connected to the mic input) or via the line-in input and then decoded and displayed by the program.

NBEMS is in active development with regular releases of new versions containing additional features and bug fixes. Consider this section of this book as a overview of NBEMS. For the latest information, please visit the official NBEMS website at www.w1hkj.com

Advantages of NBEMS: NBEMS has been rapidly growing in popularity for a variety of reasons. Training operators in use of NBEMS is relatively easy. Much of the workflow is either drag-and-drop or requires just a few mouse clicks. The user interface is much simpler than other digital modem and rig-control programs. NBEMS can be configured to automatically open and display incoming messages either in *flmsg* or your web browser without operator intervention. In *flmsg* (version 4.0 and later) there is an option to set up in an "agency" (simple) interface. This provides partner agency personnel a "dead simple" forms interface that can be used with virtually any means of transport from hard copy to e-mail to radio.

NBEMS excels on our existing analog FM repeater network. This means we don't need a dedicated digital network; we can instead leverage our existing repeaters and turn them into a digital network as needed. This allows us to combine voice and digital operations on bands easily where permitted by FCC regulations. We also find that NBEMS works very well on HF. Using

macro keys, it's easy to customize NBEMS to simplify local net operation practices, for example.

The most popular mode on VHF/UHF FM for emergency communications, MT63, works well without requiring a hardwired interface between radio and computer when using a technique known as acoustical coupling. All you need to do is hold your radio's mic up to the computer's speakers and push the radio's PTT to transmit. To receive data, just place the radio's speaker near the computer's microphone. We have found that the most difficult part of NBEMS to get to work is rig control. Use of acoustical coupling eliminates this problem. It also means we don't need to navigate a complex series of wires and cables to operate the radio or risk forgetting a cable.

All components of NBEMS are released under the GNU Public License (GPL). It is unencumbered by licenses or patents, so we can easily and freely redistribute it. It is possible to carry around a copy of NBEMS on a USB thumb drive so that it can be installed on computers as needed during an incident. Because of the GPL, there is no need to deal with software licensing issues or tracking the number of available seats that can be used in a license. Hams are able to modify or extend NBEMS because it is open source with the code available to all. Because the code is open source, we don't need to worry about what might happen should a commercial vendor go out of business or attempt to change the terms of a software license. And, because of the GPL, the cost to Amateur Radio operators is affordable: it's completely free.

NBEMS is developed and supported by an active community of ham radio operators. This means that support is readily available through mailing groups. It also means that end users have a major voice in the development of new features and improvements in usability. *Flwrap* and *flmsg* grew directly out of discussions between the NBEMS development team and ham radio operators in the emergency communications community.

NBEMS runs on *Windows*, *Linux*, and *Mac OS X* operating systems. It also works with nearly any radio on either VHF/UHF or HF. You also do not need expensive proprietary external hardware. NBEMS is technology that is inclusive to the amateur community.

Because NBEMS contains recreational modes like PSK31 and RTTY and features like contest logging and callbook lookup, you can use NBEMS between disasters, deployments, and drills. When we are called upon to serve the public, we know we will be ready because we will be using the same tools we use every day for our recreational ham radio activities, and we will know our equipment is in working order.

EchoLink

For licensed hams, EchoLink® opens up new possibilities for communicating around the world with other amateurs. Your PC links you or your local repeater to any of thousands of other stations over the Internet.

There are several different ways you can use the EchoLink. You can set up a "simplex link" in your shack, with a VHF or UHF transceiver connected to your PC, to allow anyone in range of your station to communicate by voice with any other EchoLink station around the world.

Or, you can use the PC's microphone and speakers and remotely connect to any of more than 2,000 different repeaters that have EchoLink capability.

Related Considerations

Become familiar with and practice using any digital mode or system well in advance of an emergency. Most are complex enough that some experience is required to use them efficiently and effectively.

Digital communications can be enhanced by composing the message off-line in a text editor. With a little ingenuity, “fill in the blank” forms can be created in most word processors to reduce the amount of typing required and help standardize message formats. For packet communication, consider an emergency communications-specific program like ARESPACK, http://www.laarc.org/arespack.PDF

The high duty-cycle of many digital modes requires a rugged radio and power supply with adequate cooling. Test your equipment under field conditions for an extended period to identify any possible problems.

Reference Links

Amateur Radio Emergency Data Network (AREDN)
https://www.arednmesh.org/

ARRL web page on digital modes
www.arrl.org/digital-modes

DMR
www.dmr-marc.net/

EchoLink
www.echolink.org/

HSMM
https://www.arrl.org/shop/High-Speed-Multimedia-for-Amateur-Radio/

NBEMS and fldigi
www.w1hkj.com

Olivia
www.oliviamode.com/

Winlink
www.winlink.org/

WSJT
https://physics.princeton.edu/pulsar/k1jt/

Review

Choosing the correct mode and frequency for each type of message will make your nets more efficient and improve service to your partner. Voice modes are low-precision, multi-point modes, and many digital modes are high-precision point-to-point modes. Sometimes Amateur Radio is not the best way to send a message. Confidential messages are best sent via telephone, fax, or courier.